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A resistance band increased internal hip abduction moments and gluteus medius activation during pre-landing and early-landing

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ABSTRACT

An increased knee abduction angle during jump-landing has been identified as a risk factor for anterior cruciate ligament injuries. Activation of the hip abductors may decrease the knee abduction angle during jump-landing. The purpose of this study was to examine the effects of a resistance band on the internal hip abduction moment and gluteus medius activation during the pre-landing (100 ms before initial contact) and early-landing (100 ms after initial contact) phases of a jump–landing–jump task. Thirteen male and 15 female recreational athletes (age: 21.1 ± 2.4 yr; mass: 73.8 ± 14.6 kg; height: 1.76 ± 0.1 m) participated in the study. Subjects performed jump–landing–jump tasks with or without a resistance band applied to their lower shanks. During the with-band condition, subjects were instructed to maintain their movement patterns as performing the jump-landing task without a resistance band. Lower extremity kinematics, kinetics, and gluteus medius electromyography (EMG) were collected. Applying the band increased the average hip abduction moment during pre-landing ($p < 0.001$, Cohen's d (d)=2.8) and early-landing ($p < 0.001$, $d = 1.5$), and the average gluteus medius EMG during pre-landing ($p < 0.001$, $d = 1.0$) and early-landing ($p = 0.003$, $d = 0.55$). Applying the band decreased the initial hip flexion angle ($p = 0.028$, $d = 0.25$), initial hip abduction angle ($p < 0.001$, $d = 0.91$), maximum knee flexion angle ($p = 0.046$, $d = 0.17$), and jump height ($p = 0.004$, $d = 0.16$). Applying a resistance band provides a potential strategy to train the strength and muscle activation for the gluteus medius during jump-landing. Additional instructions and feedback regarding hip abduction, hip flexion, and knee flexion may be required to minimize negative changes to other kinematic variables.

1. Introduction

Anterior cruciate ligament (ACL) injuries typically occur in the early phase of landing when individuals demonstrate a decreased knee flexion angle and an increased knee abduction angle (Agel et al., 2005; Boden et al., 2000; Koga et al., 2010; Krosshaug et al., 2007). A decreased knee flexion angle and an increased external knee abduction moment are associated with an increased ACL loading (Berns et al., 1992; Markolf et al., 1995). An increased peak knee abduction angle and an increased peak external knee abduction moment during jump-landing have been identified as risk factors for ACL injuries (Hewett et al., 2005). Therefore, landing with a small knee abduction angle may decrease ACL loading and the risk of ACL injuries.

The lower extremity acts as a kinetic chain during dynamic tasks (Powers, 2003, 2010). Excessive hip adduction during landing can cause the knee joint to move medially, and increase the knee abduction angle (Powers, 2003, 2010). Activation of the hip abductors can generate an internal hip abduction moment to decrease the medial displacement of the knee and knee abduction angle. Investigators have studied the relationships between the hip abductor strength, hip abductor activation, and knee abduction angle during landing and squatting tasks (Homan et al., 2013; Jacobs and Mattacola, 2005; Jacobs et al., 2007; Patrek et al., 2011; Russell et al., 2006; Wallace et al., 2008; Zeller et al., 2003), but limited intervention strategies are available to train the hip abductors during jump-landing. Several investigators have described hip abductor activation during functional tasks (Boudreau et al., 2009; Distefano et al., 2009; Dwyer et al., 2010), however, muscles demonstrate specificity between training and testing tasks for strength gains (Hortobagyi et al., 1996; Rutherford and Jones, 1986; Wilson et al., 1996). The transfer effect from functional tasks to athletic tasks may be limited. In addition, because ACL injuries usually occur in the early phase of landing (Koga et al., 2010; Krosshaug et al., 2007), activation of the hip abductors during early landing or even before landing should be encouraged. Functional tasks may have limited training effects on specific muscle activation patterns during athletic tasks.

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The ACL research Retreat VI group has stated that it is needed to "optimize the transfer of learned movement patterns to sports-specific movements performed on the field" (Shultz et al., 2012). Strategies to train the strength and muscle activation for the hip abductors during athletic tasks may be more applicable to the sports field.

One way to train the hip abductors is to apply a resistance band between an individual's lower extremities (Cambridge et al., 2012; Distefano et al., 2009). Applying a resistance band to the lower extremities can produce a medial force and an external hip adduction moment, which may increase the demands of the hip abductors to generate a counteracting internal hip abduction moment. Cambridge et al. (2012) placed a resistance band on individuals' knees, ankles, and feet during Sumo Walking and Monster Walking. These researchers found that the electromyography (EMG) of the gluteus medius increased as a result of the band placement moving distally. Gooyers et al. (2012) evaluated the effects of a resistance band on knee width indices and peak external knee abduction moments during squatting and jumping tasks. However, the effects of a resistance band on hip joint moments and hip abductor activation during jump-landing are still unknown.

The primary purpose of this study was to quantify the effects of a resistance band on internal hip abduction moments and gluteus medius activation during the pre-landing and early-landing phases of a jump–landing–jump task. A secondary purpose was to assess the effects of a resistance band on knee and hip biomechanics and task performance during the same phases of landing. It was hypothesized that a resistance band would increase internal hip abduction moments and gluteus medius activation without negatively affecting knee and hip biomechanics and task performance.

2. Methods

2.1. Subjects

Based on a pilot study with two subjects and a previous study (Cambridge et al., 2012), a medium to large effect size was expected for the internal hip abduction moment and gluteus medius EMG between the without-band and with-band conditions. Assuming an effect size of 0.6 for a paired test, a total sample size of 24 was needed for a type I error at the level of 0.05 to achieve a power of 0.8.

A total of 28 recreational athletes (gender: 13 males, 15 females; age: 21.1 ± 2.4 yr; mass: 73.8 ± 14.6 kg; height: 1.76 ± 0.1 m) participated in the study. The subjects were required to have experience in playing sports that involved jump-landing tasks. Sports experience was defined as currently playing sports at least one time per week or having previously played at high school, college, or club levels. Subjects were also required to be currently physically active, which was defined as participating in sports / exercise at least two times per week for a total of 2–3 hours per week. A subject was excluded if he/she previously had one of the following conditions: (1) an ACL injury or other major lower extremity injuries; (2) a lower extremity injury that prevented participation in physical activities for more than two weeks over the previous six months; and (3) a condition that prevent him/her from participating in sporting activities. Permission to conduct this study was obtained from the University of Wyoming Institutional Review Board.

2.2. Procedures

Subjects wore spandex shorts, shirts, and standard running shoes (Ghost 5, Brooks Sports, Bothell, Washington). Subjects performed 5-min of self-selected running and stretching exercises for warm-up. The testing side (left or right) was randomly selected. On the testing side, a surface electrode was placed on the muscle belly of the gluteus medius, defined as 50% on the line from the iliac crest to the greater trochanter (Bolgla and Uhl, 2007). A reference electrode was placed on the tibial tuberosity. A proper electrode placement was confirmed by visual inspection of the EMG when subjects abducted their hips against a manual resistance. A harness (Fig. 1) was placed above the subjects' pelvis to hold the EMG transmitter (Myomonitor, Delsys Inc, Boston, MA). EMG data were collected at a sampling frequency of 2000 Hz using EMGworks software (Delsys Inc, Boston, MA). Retroreflective markers (Fig. 1) were placed on subjects' bony landmarks. Marker co-ordinates were captured using six optical cameras at a sampling frequency of 160 Hz (Vicon Bonita 10, Oxford Metrics Ltd, Oxford, UK). Ground reaction forces were collected using a force plate at a sampling frequency of 1600 Hz (4060-10, Bertec, Columbus, OH).

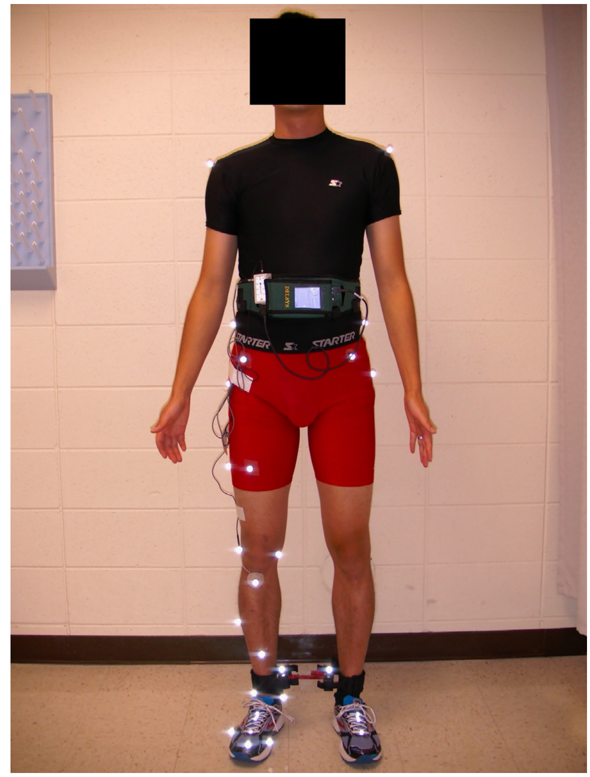

Fig. 1. Mark placement and EMG transmitter.

Subjects performed a standing trial and multiple trials of a jump–landing–jump task (Padua et al., 2012b) (Fig. 2) with or without a resistance band (LifeLineUSA, Madison, WI; Fig. 3). The cuffs of the band were placed right above the ankle joints. The rest length of the band was set in such way that the distance between the centers of the two ankle cuffs was 15 cm, which was generally shorter than an adult's stance width. Two markers were placed on the cable pockets to define the length of the band and the direction of the force generated by the band. The length–force relationship of the band was calibrated during each data collection by slowly lifting a constant weight from a force plate (Fig. 4). During the calibration, the length of the band was defined by the two markers. The force generated by the band was calculated by subtracting the vertical ground reaction force from the constant weight. Subjects performed 2 or 3 practice trials without the resistance band to ensure correct jump-landing forms. Additional practice trials were allowed before the official trials if required. Subjects then performed 3 official trials of the jump–landing–jump task with or without a resistance band (randomized order). In the with-band condition, subjects were instructed to maintain their movement patterns as performing the jump-landing without a resistance band. Subjects had a 30-second break between two trials to avoid fatigue. After completing jump-landing trials, subjects performed a 10-second hip abductor maximum voluntary isometric contraction (MVIC) against a stationary weight in a standing posture, with hip joint angles at 0 degree in all three anatomical planes. EMG data were collected during the 10-second MVIC trial to ensure a true 1-second MVIC was achieved.

2.3. Data reduction

Marker co-ordinates and force plate data were filtered using a fourth-order, zero-phase-shift Butterworth filter at a low-pass cutoff frequency of 15 Hz (Kristianslund et al., 2012). EMG data were filtered at a high-pass cutoff frequency of 20 Hz and a low-pass cutoff frequency of 450 Hz. Filtered EMG data were rectified and filtered at a low-pass cutoff frequency of 10 Hz to obtain the linear envelope EMG (Dai et al., 2012). EMG data during jump-landing were normalized as a percentage of the maximum 1-second average EMG during MVIC. Marker co-ordinates, force, and EMG data were time-synchronized to 160 Hz using a linear interpolation method.

The hip joint center was determined according to Bell et al. (1990). The knee joint center was determined as the midpoint between the medial and lateral femoral epicondyles (Kadaba et al., 1989). The ankle joint center was determined as the midpoint between the medial and lateral malleoli (Kadaba et al., 1989). The pelvis reference frame was defined by the right and left anterior superior iliac spines and midpoint between the right and left posterior superior iliac spines (Wu et al., 2002).